Integration Technology and Tools Development for IES and ORNL CHP Integration Laboratory-Overview

Patti W. Garland

Oak Ridge National Laboratory

Integrated Energy Systems (IES)

Peer Review Meeting

Nashville, Tennessee

May 1, 2002

OAK RIDGE NATIONAL LABORATORY

MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

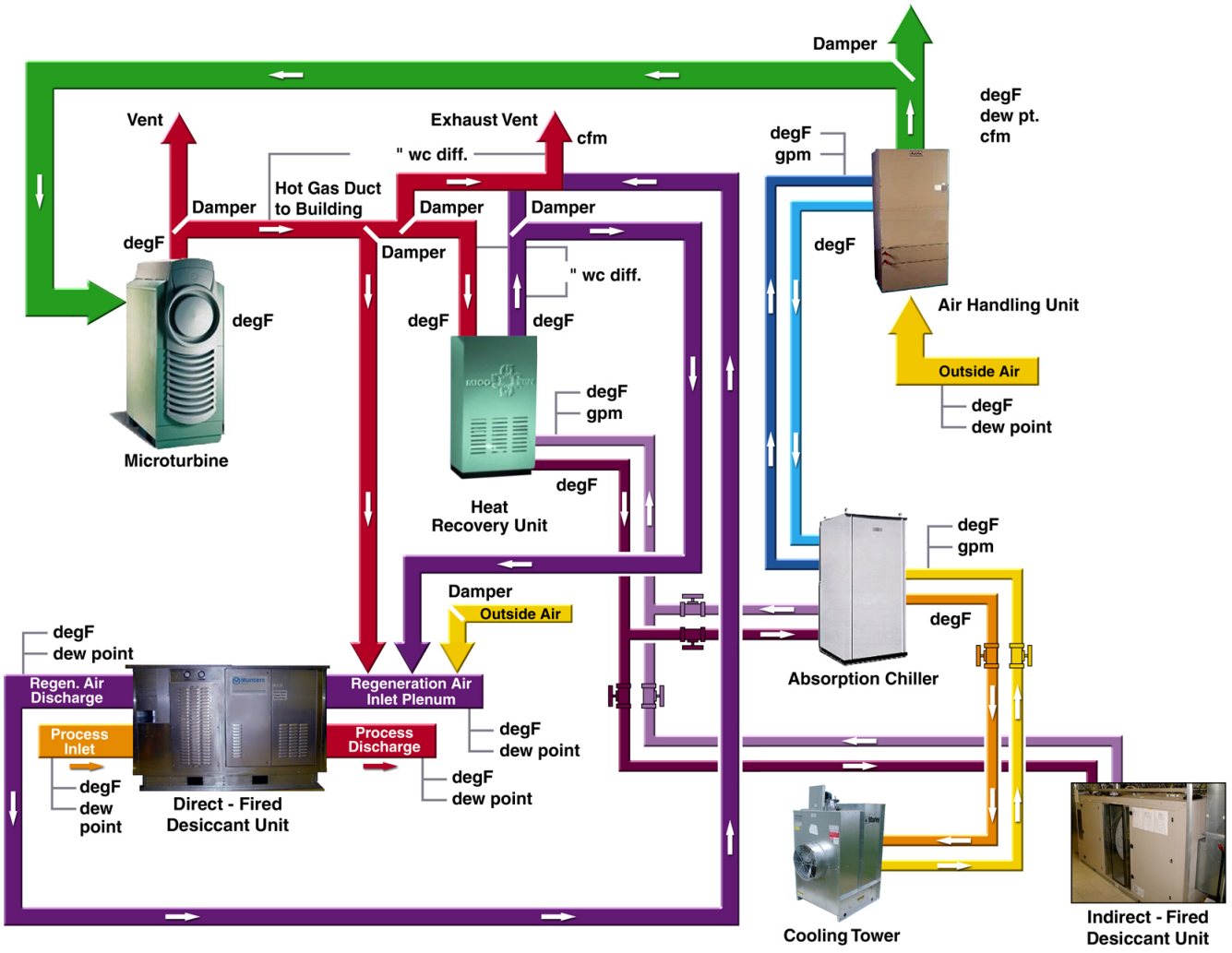
Presentation Outline

- CHP Integration Test Laboratory at ORNL
- CHP Commercial Building Integration Test Center at University of Maryland
- Analytical Tools Development for CHP

Overall Objectives of CHP Integration Laboratory at ORNL

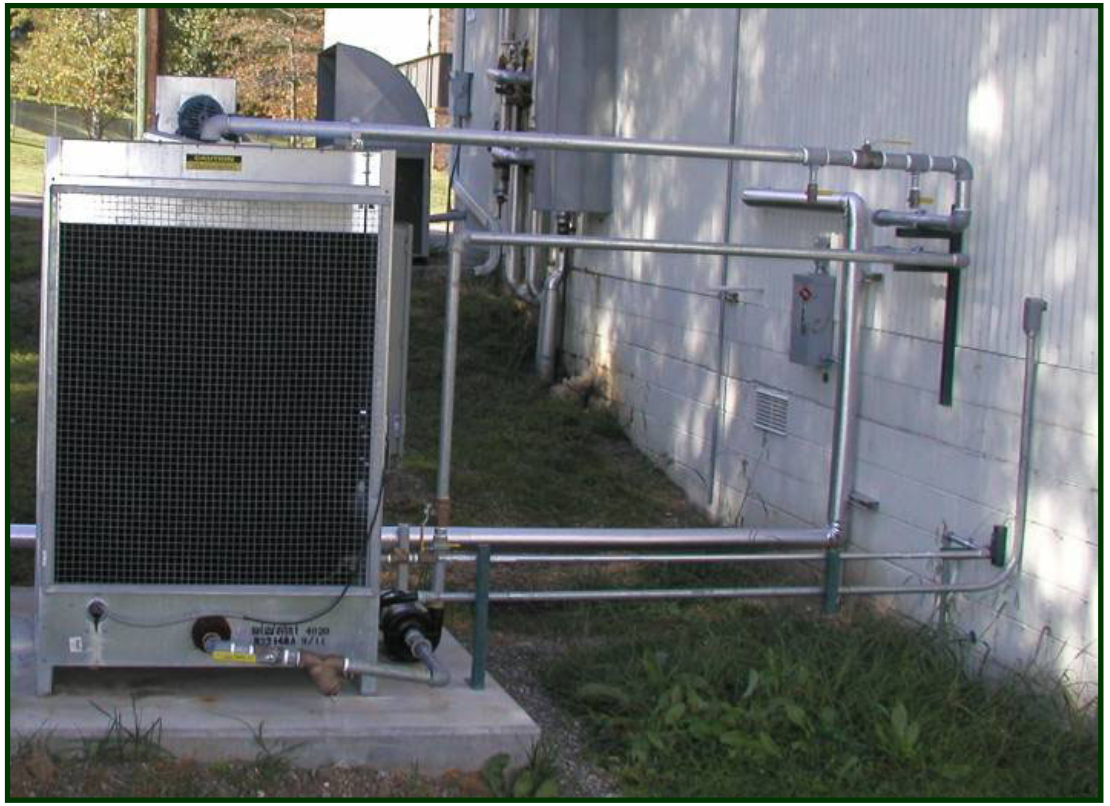
- Benchmark Microturbine-based CHP System performance and emissions
- Provide data for computer algorithms,model validation
- DG/TAT equipment integration R&D, alternatives evaluation, performance optimization in cooperation with packaged IES manufacturers
- Provide diagnostic support for Field Test data analysis
- Support rating/certification Standards for IES Products
- Advanced technology, designs for “Next Generation” IES products

CHP Integration Test Facility



CHP Test Facility Configuration (outdoors)

30-kW Microturbine



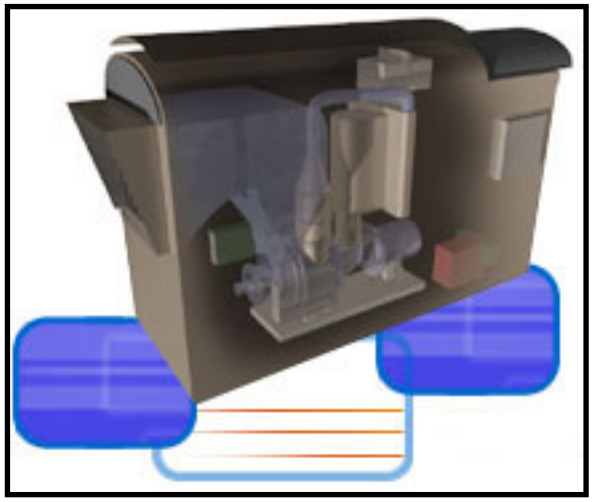
Cooling Tower for 10-Ton (35-kW) Single-Effect Absorption Chiller

CHP Test Facility Configuration (indoors)

Exhaust Heat Recovery Test Loops

IES Vision
Packaged System Integration

2002: Individually optimized products combined on-site

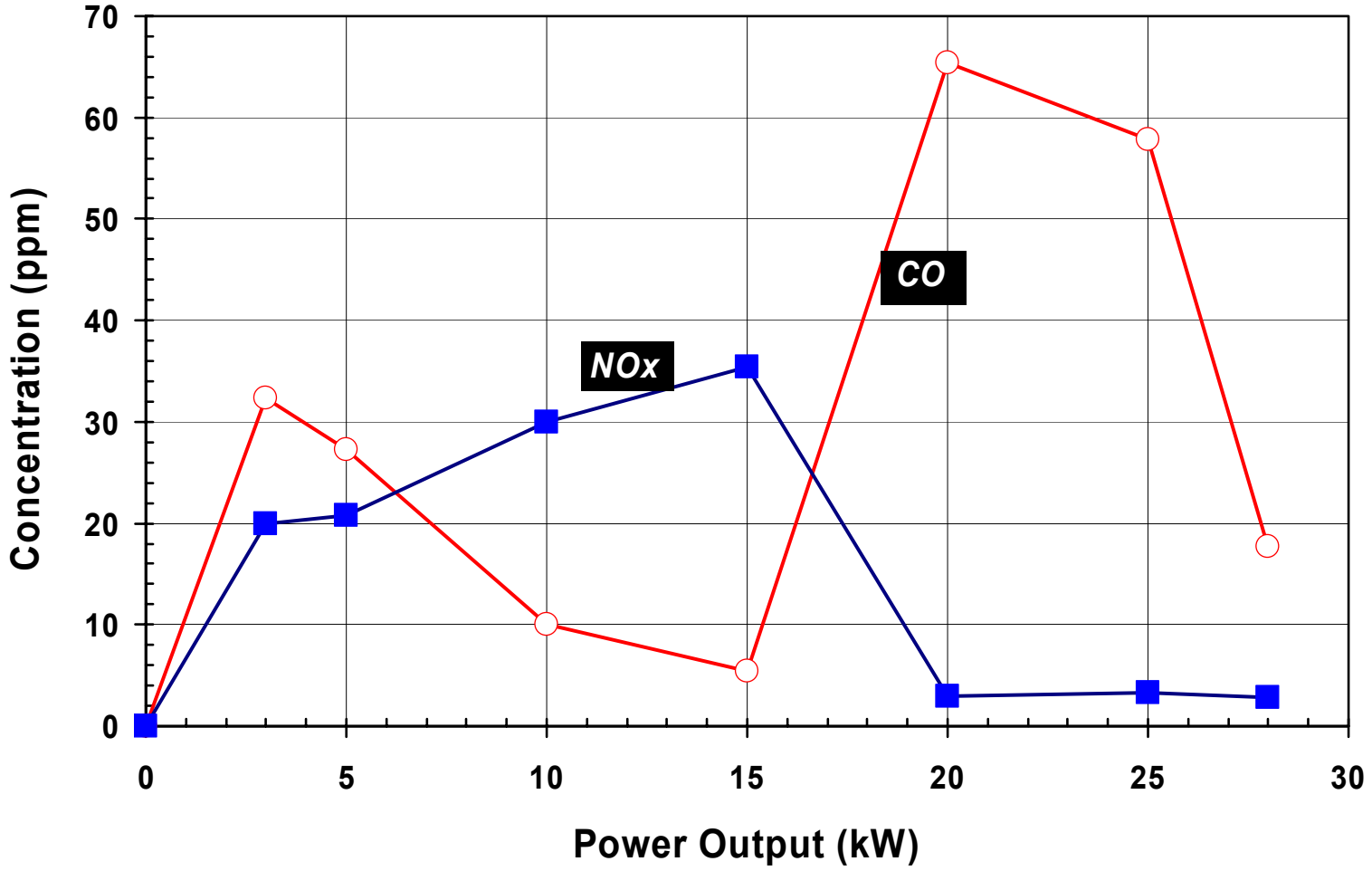


2010: IES - single optimized package from manufacturer

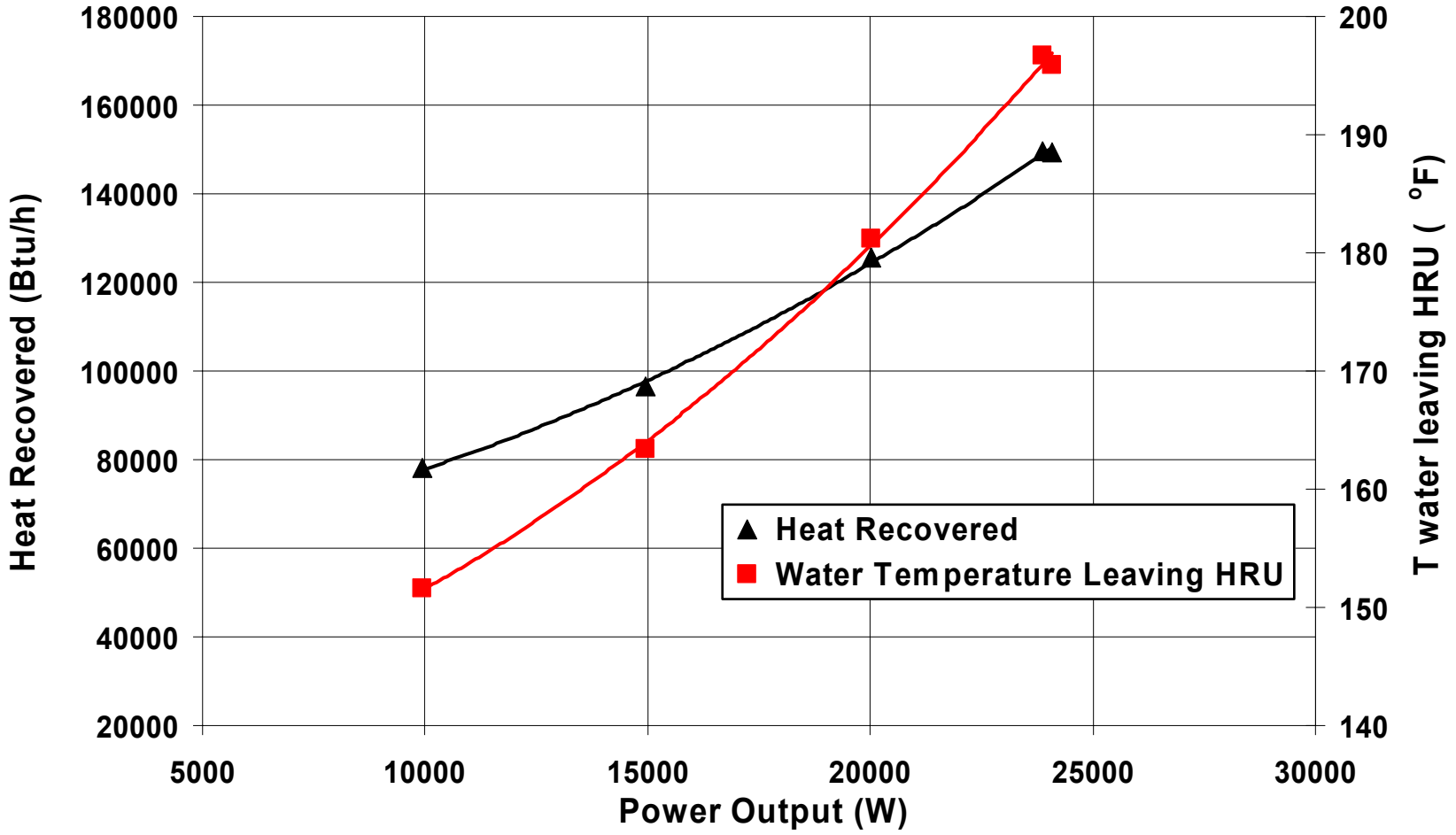
Planned Sequence of CHP Performance Testing

- Microturbine Baseline Performance Testing
- Heat Recovery Unit (HRU) – Exhaust to Water Heat Exchanger
- Indirect-Fired Desiccant Dehumidifier
- Direct-Fired Desiccant Dehumidifier
- Indirect-Fired Absorption Chiller and Turbine Inlet Air Cooling

Flue Gas Emissions Lowest at Full Power Output

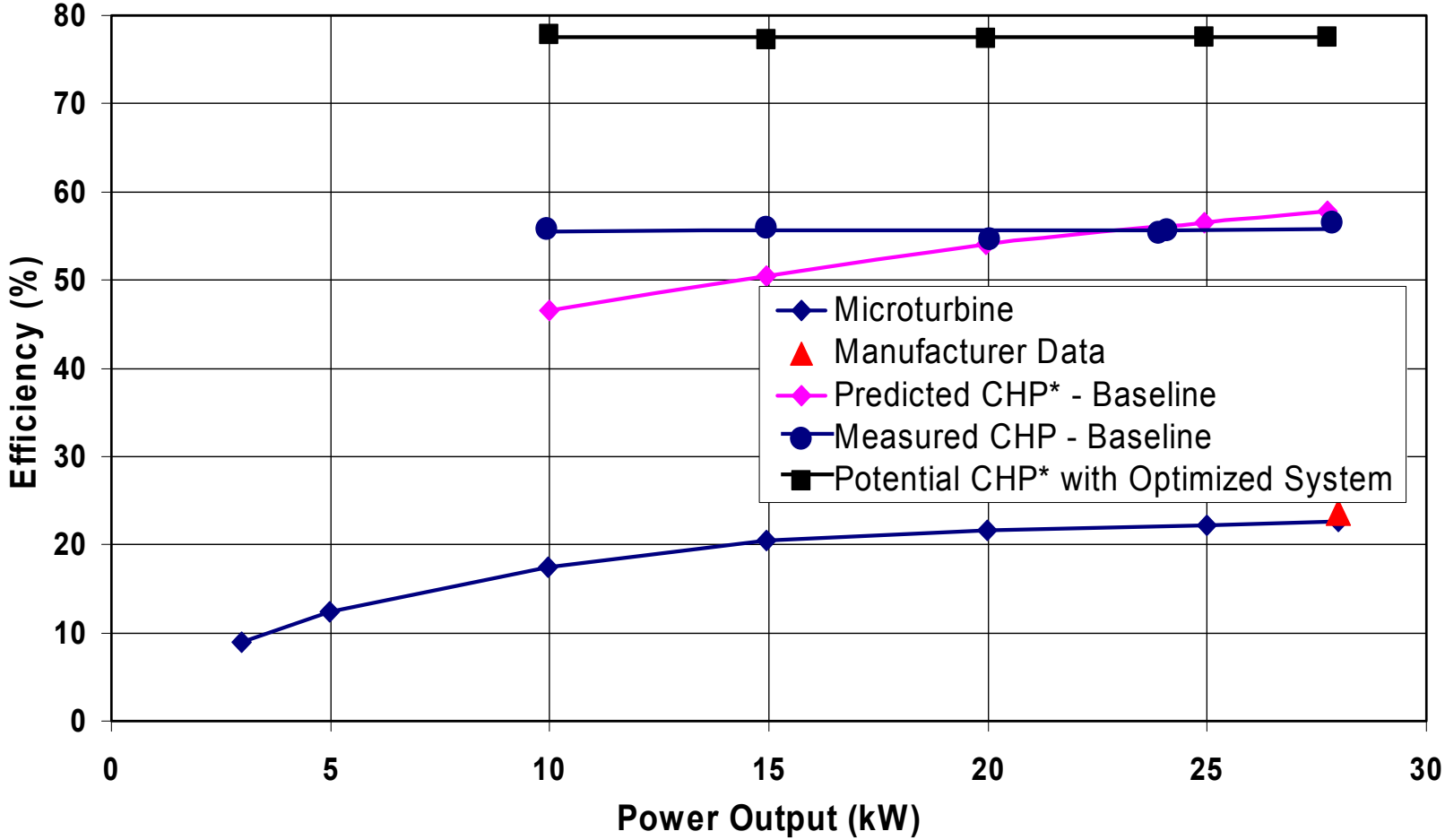


Heat Recovery in the HRU at Various Power Output



Results with water flow rate of 19 gpm (4.3 m^3/h)

Microturbine and CHP Efficiencies Measured vs. Predicted



*Based on 127°C (400K) or 260°F flue gas rejected to the atmosphere, HHV for natural gas

Accomplishments

- **Microturbine Performance and Emissions over a Wide Range of Power Outputs, Backpressures and Ambient Conditions**
  - **CHP Efficiency of Almost 60% From 10 kW to 28 kW**
    - **Overall CHP Efficiency Remain Constant Even Though Electric Efficiency Drops at Part Load**
    - **80+% Possible For Optimized System**
  - **Exhaust Backpressure of 7” wc has minimal effect on kW and efficiency – No Design Constraint on HR Components**
  - **Low Emissions At Full Power**
- **Development/Verification of a Mathematical Model**
  - **Completed Modeling of Microturbine and Heat Recovery Unit**
  - **Close Agreement Between Predicted and Measured CHP Efficiencies**

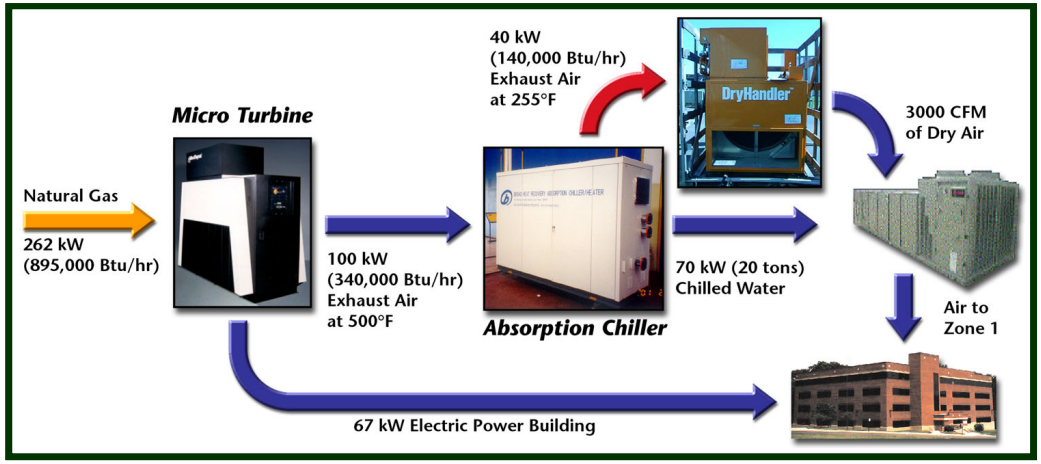
Future Work

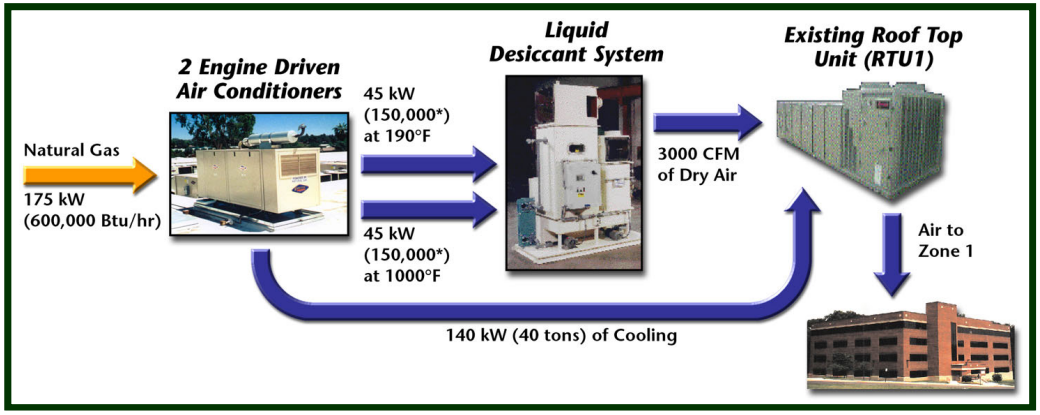
- **CHP Tests**
  - **Alternative Configurations and Performance Trade-Off Evaluations**
  - **Thermal Storage Integration and Advanced Heat Recovery Evaluation**

- **Modeling Effort Proceeding**
  - **With Modeling of Indirect/Direct-Fired Desiccant Dehumidifiers and Indirect-Fired Absorption Chiller**
  - **With Optimization of design and operating parameters of individual units**
  - **With Optimization of CHP system under different loads**

University Test Center for IES/Building Integration CHP

University of Maryland, College Park





- Integrate IES into building, HVAC System
- Test advanced controls, diagnostics, operating strategies

CHP Integration Test Center Project Objectives

- Integrate equipment into CHP systems
- Integrate CHP systems into commercial buildings
- Demonstrate performance potential in an occupied building
- Test advanced control systems
- Provide essential technical knowledge to manufacturing partners

Professional Collaboration

- ORNL – Sensors (CO_2 and Humidity)
- PNNL – Whole Building Diagnostician
- NREL – Liquid Desiccant Components
- Energy Storage (DOE, Energetics, NRECA, Sandia – Distributed Energy Technology Simulator)
- Southern Research Institute, EPA, Honeywell – Independent Verification of Micro-Turbine Performance and Emissions
- ORNL – Integrated System Performance Evaluation

Software Tools, Models Needed for IES Applications Screening and Design Analysis

- Technology Roadmapping included strong contribution, recommendation from Energy Analysis experts
- Screening Tool for CHP in Buildings applications identified as high priority
- GARD Analytics selected in competitive solicitation to develop “BCHP Screening Tool”
- RFP Work Statement took advantage of then current DG-CHP software evaluation project
- Evaluation of DG-CHP models and analysis software has continued in parallel

CHP Software Characteristics

- Type of Analysis
  - Preliminary assessment
    - BCHP Screening Tool, DisGenie, Ready Reckoner, D-Gen Pro
  - Detailed design
    - Gatecycle, SOAP-CT24, Thermoflow
- Results
  - Energy calculations
    - BCHP Screening Tool, DisGenie, Ready Reckoner, Gatecycle, D-Gen Pro, SOAP-CT24, Thermoflow
  - Economic calculations
    - BCHP Screening Tool, DisGenie, Ready Reckoner, D-Gen Pro, SOAP-CT24, Thermoflow

http://www.eren.doe.gov/der/chp/chp-eval2.html

BCHP Screening Tool Software: Strengths and Progress

- BCHP Screening Tool provides "information at fingertips" for preliminary assessment
  - Other models for preliminary assessments require extensive input from the user for utility rates, building loads, and equipment performance
- Detailed design models provide rigorous analysis of energy use and economics
  - Lack building load calculations, utility rates, and HVAC equipment
- Beta version distributed to 80 "testers" April 2002 (including equipment manufactures and IES Teams)

Analysis Tools – Future Steps

- Verification of analysis and design tools by comparison with field performance data
- Development and validation of IES models, algorithms
- Incorporation of IES models "library," utility rates, and electrical/thermal load databases into existing design and energy analysis tools

List of Publications

- "Experimental and Theoretical Study of Gas Microturbine-Based BCHP System," International Mechanical Engineering Congress and Exposition, 2001.
- "Predictive Algorithms for Microturbine Performance for BCHP Systems, ASHRAE Transactions, 2002.
- "DER Performance Testing of a Microturbine-Based Combined Cooling, Heating, and Power (CHP) System," Power System Conference, 2002.
- "Power Quality and The Control of DG on Distribution Systems," Power System Conference, 2002.

List of Publications (Cont'd)

- "Steady-State and Dynamic Performance Characterization Testing of a Microturbine," Power System Conference, 2002.
- "Integration of Distributed Energy Resources and Thermally-Activated Technologies" Distributech Conference, 2002.
- "Study of Flue Gas Emissions of Gas Microturbine Used in BCHP System" Journal of Power Plant Chemistry (submission).
-
- "Environmental Aspects of Operation of Gas Microturbine-Based CHP System" Nineteenth Annual International Pittsburgh Coal Conference, 2002.

List of Publications
(Cont'd)

- "The Potential of CHP Technology in Commercial Buildings - Characterizing the CHP Demonstration Building," ASHRAE Symposium on CHP Technologies for the New Century, 2002.
- "Integration of a Microturbine with a Single Effect Exhaust Driven Absorption Chiller and a Solid Wheel Desiccant System," ASHRAE Transactions 2002.
- "Environmental Analysis of Two Cooling, Heating and Power Systems for Commercial Buildings," Building Energy Journal, 2001.
- CHP for Buildings: "The Challenge of Delivering Value to the Commercial Sector" ASME (in review), 2002.

DG-CHP Software Evaluation: Known Models

- Thermoflow Program Suite
- SOAP-CT24 (EPRI/GRI)
- D-Gen Pro (GRI)
- Gatecycle (GE)
- Ready Reckoner (Australian Gov't and Australian Ecogeneration Association)
- DisGenie (Thermax)
- BCHP Screening Tool (U.S. DOE)
- HeatMap4 (Washington State University)

http://www.eren.doe.gov/der/chp/chp-eval2.html